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HYDROCYANIC ACID GAS.

ITS PRACTICAL USE AS A ROUTINE FUMIGANT.

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The toxicity of hydrocyanic acid gas to all animal life and the effectiveness of this gas in destroying vermin are well known, but the minimum dilution that can be depended upon to accomplish satisfactorily the object sought has not been fully determined.

NOTE.—Fumigation with hydrocyanic acid gas should be carried out only by responsible persons, thoroughly familiar with the nature of the reagents used and their poisonous properties and the danger to man and animals of inhaling even comparatively small quantities of the gas during or after fumigation.

Because of the dangers associated with fumigation with hydrocyanic acid gas, the Surgeon General has issued the following instructions to officers of the Public Health Service to be followed in the fumigation of vessels:

When performing the cyanide fumigation of compartments you will be guided by the following minimum requirements:

1. On account of the great danger to human life from hydrocyanic acid gas, specific arrangements should be made for the disposition of the crew during the fumigation process, especially if one or two compartments of a vessel are to be treated. A written statement must be obtained from the captain or first officer of the vessel that the latter is ready for fumigation, and that every member of the crew has been accounted for, as not being in the vessel or else not exposed to the fumes of the gas. Persons in one compartment have been killed by fumes escaping from another compartment undergoing fumigation.

2. Not less than 5 ounces of potassium cyanide or 3¾ ounces of sodium cyanide shall be used to each 1,000 cubic feet of space, inclusive of that occupied by cargo.

3. To each ounce of potassium cyanide 1 fluid ounce of commercial sulphuric acid 66B and 2½ fluid ounces of water shall be used.

4. To each ounce of sodium cyanide 1½ fluid ounces of commercial sulphuric acid 66B and 2 fluid ounces of water shall be used.

5. All ingredients shall be weighed and mixed immediately prior to each fumigation.

6. All parts of the vessel shall be placed under fumigation simultaneously except such compartments as may not require fumigation in the opinion of a representative of the United States Public Health Service. (Review par. 1.)

7. All compartments placed under fumigation shall be kept closed for not less than one hour.

8. The hatches of 'tween decks and the doors of subcompartments are to be opened prior to fumigation, and the barrel or other generator is to be placed so as to secure the most rapid and efficient diffusion of the gas.

9. All work is to be done under the supervision and to the satisfaction of the medical officer in charge, United States Public Health Service, or his representative.—EDITOR.

One ounce of potassium cyanide per 100 cubic feet of space is the (standard) amount generally used, and is the quantity advocated by Surg. Norman Roberts.[1] The expensiveness of the reagents and the danger to human life have been considered sufficient to preclude the common use of this gas for fumigation.

The relatively high cost of potassium cyanide and sulphuric acid (more especially where the purified products are used) has been largely responsible for the limited use of hydrocyanic acid gas in fumigating ships.

Obviously, the smaller the amount of hydrocyanic acid gas used compatible with effectiveness, the wider the range of its applicability from an economic standpoint.

If the percentage of gas could be reduced to a sufficiently low degree to make the price of the material no greater than that of other fumigants, at the same time retaining its potency for the destruction of vermin, the chief objection to the widespread use of hydrocyanic acid gas would be removed.

In order to clear up this question, a series of practical experiments was determined upon and carried into effect.

In addition to the consideration of the main point involved, study was given several other elements entering into cyanide fumigation.

These were as follows:

First. The relative penetrating power of cyanide gas in comparison with other fumigants most generally in use, more especially sulphur dioxide.

Second. The least duration of exposure necessary to assure the destruction of rodents and rodent parasites under the natural conditions obtaining in ships and in buildings.

Third. The relative cost of cyanide fumigation in comparison with that of sulphur dioxide and carbon monoxide (funnel gas).

Fourth. The danger to human life in performing cyanide fumigation.

Comparative Values of Various Fumigants.

A comparison of the three most frequently used fumigants, sulphur dioxide, carbon monoxide, and hydrocyanic acid gas, reveals many facts favoring the use of hydrocyanic acid gas as a routine fumigant in both ships and buildings for the destruction of rodents.

Sulphur dioxide, while fairly effective, is not very penetrating. It diffuses very poorly, and in actual practice it has seemed that air pockets in articles of cargo or between packages will afford to rats a sufficient protection against the effect of the sulphur fumes.

[1] Norman Roberts, surgeon, U. S. Public Health Service. Public Health Reports, Dec. 11, 1914, vol. 29, No. 50.

Grubbs's[1] observations along this line were confirmed by the experiments of the writers. Its use is highly destructive to various articles, and its generation requires cumbersome apparatus and the expenditure of considerable time. Being less toxic than hydrocyanic acid gas or carbon monoxide, sulphur dioxide requires a much longer exposure. The exposure to sulphur fumes requires from 6 to 12 hours in contrast to less than 1 hour when hydrocyanic acid gas is used. The lack of diffusive qualities limits the use of sulphur dioxide almost exclusively to the fumigation of vessels in ballast.

Carbon monoxide, while highly efficient, requires such complicated apparatus for its generation that the use of this gas as a fumigant is restricted to quarantine stations or other localities where proper care and attention can be given to the apparatus required. Moreover, this gas is valueless for the destruction of the lower forms of animal life, fleas, flies, and mosquitoes.

To the disadvantages of both of these fumigants must be added the danger of fire, a necessary attendant to the generation of either of these gases.

Hydrocyanic acid gas is the most penetrating and the most toxic of these fumigants. It is easily and quickly generated, requires very little apparatus, is not destructive to inanimate objects, and in the hands of experienced operators its use is not attended by more danger to persons than is the use of carbon monoxide.

The following experiments were performed, part of them on ships, the others in a sealed room on land:

Experiment No. 1.

Two rats in separate wire cages were placed near the closed portholes in a steel-walled room of a ship. Part of this stateroom was occupied by bunks and sailors' clothing and equipment. The gas was generated from one container placed near the center of the room. One cage was lightly covered with a piece of white-duck cloth. Potassium cyanide in lump form, wrapped in gauze, was dropped by hand into the sulphuric acid.

Capacity of the room, approximately	cubic feet	1,395
Amount of lump commercial potassium cyanide	ounces	14
Amount of 66B sulphuric acid	do	22

Effect of gas on rat No. 1 noticed in 5½ minutes.
Effect of gas on rat No. 2 noticed in 7 minutes.
Respiratory efforts of rat No. 1 ceased in 33 minutes.
Respiratory efforts of rat No. 2 ceased in 41 minutes.
Strength of gas, 1 ounce cyanide per 100 cubic feet of space.

[1] S. B. Grubbs, surgeon, and B. E. Holsendorf, pharmacist, U. S. Public Health Service. Public Health Reports, June 20, 1913, vol. 28, No. 25.

Experiment No. 2.

One rat in a wire cage was placed in the hold of a ship filled with miscellaneous cargo. Capacity of hold when empty, 122,000 cubic feet.

	Pounds.
Amount of commercial potassium cyanide	54
Amount of 66B sulphuric acid	54

Strength of gas, 0.708 ounces of cyanide per 100 cubic feet of space.

The rat was dead when removed from the hold after 1 hour and 30 minutes' exposure.

Experiment No. 3.

One rat in a wire cage was placed in the hold of a ship, partly filled with miscellaneous cargo, immediately over the cyanide generator. Capacity of hold when empty, 65,000 cubic feet.

	Pounds.
Amount of commercial potassium cyanide	36
Amount of 66B sulphuric acid	36

Strength of gas, 0.886 ounce of cyanide per 100 cubic feet space.

The rat was dead when removed from the hold after a period of 10 minutes' exposure.

Experiment No. 4.

One rat in a wire cage was placed in the hold of a ship filled with miscellaneous cargo. The rat was placed as far as possible from the generator, the gas having to pass through the intervening bulk of cargo before reaching the animal.

Capacity of hold when empty	cubic feet	122,000
Amount of commercial potassium	pounds	27
Amount of 66B sulphuric acid	do	27

Strength of gas, 0.354 ounces of cyanide per 100 cubic feet of space.

The rat was removed after 10 minutes' exposure. Apparently it was not affected. No odor of cyanide could be detected and the rat was immediately replaced. At the end of 20 minutes the rat was again withdrawn and found still breathing, but apparently beyond the power of voluntary movement. The odor of cyanide was very noticeable. This rat revived at the end of 30 minutes.

Experiment No. 5.

Two rats in a wire cage were placed in the hold of a ship filled with miscellaneous cargo. The cage was completely covered with sacks of potatoes and onions to afford the maximum amount of protection to the rodents against exposure to the gas.

Capacity of hold when empty	cubic feet	122,000
Amount of commercial potassium cyanide	pounds	27
Amount of 66B sulphuric acid	do	27

Strength of gas, 0.354 ounce of cyanide per 100 cubic feet of space.

The rats were withdrawn, dead, at the end of one hour's exposure. From their appearance it was judged they had succumbed during the early part of the experiment.

Two other rats escaped from a cage which was being lowered into the hold of the vessel some time previous to generation of gas. Subsequently they were both found dead amongst the cargo where they had sought refuge.

The following experiments were performed in a room, the floor, ceiling, and walls and all openings of which had been thoroughly sealed.

Experiment No. 6.

Two rats in separate wire cages were placed in the room on chairs near the window, where every action could be watched. The gas was generated from a single container placed near the center of the room. The cyanide used was in lump form, wrapped in cheesecloth, and dropped into the acid by hand.

Capacity of the room, 1,269 cubic feet.
Amount of chemically pure potassium cyanide in lump form, 12.69 ounces.
Amount of sulphuric acid, specific gravity 1.84, 12.69 ounces.
Strength of gas, 1 ounce of cyanide per 100 cubic feet of space.
Effects of gas on rat No. 1 noticed in 2½ minutes.
Effects of gas on rat No. 2 noticed in 3 minutes.
Respiratory efforts of rat No. 1 ceased in 10 minutes.
Respiratory efforts of rat No. 2 ceased in 10 minutes.

Full action of acid on cyanide was not complete until five minutes after death of the rats.

Experiment No. 7.

Two rats in separate wire cages were used.

	Ounces.
Amount of powdered chemically pure potassium cyanide	12.69
Amount of 66B sulphuric acid	12.69

Strength of gas, 1 ounce of cyanide per 100 cubic feet of space.
Effects of gas on rat No. 1 noticed in one minute.
Effects of gas on rat No. 2 noticed in one minute.
Respiratory efforts of rat No. 1 ceased in five minutes.
Respiratory efforts of rat No. 2 ceased in five minutes.

Experiment No. 8.

Three rats in separate wire cages were placed in the room. One of these, a banana rat, carried nine young apparently less than a week old.

	Ounces.
Amount of powdered chemically pure potassium cyanide	6.34
Amount of sulphuric acid, specific gravity, 1.84	6.34

Strength of gas, 0.5 ounce of cyanide per 100 cubic feet of space.
Effects of gas on banana rat noticed in six minutes.
Effects of gas on rat No. 2 noticed in six minutes.
Effects of gas on rat No. 3 noticed in eight minutes.
Respiratory efforts of banana rat ceased in 11 minutes.
Respiratory efforts of rat No. 2 ceased in 10 minutes.
Respiratory efforts of rat No. 3 ceased in 12 minutes.

The powdered cyanide was inclosed in a double thickness of cheesecloth.

Experiment No. 9.

Four rats were used. Nos. 1 and 2 were placed in separate wire cages; Nos. 3 and 4 turned loose in the room.

	Ounces.
Amount of powdered commercial potassium cyanide	5
Amount of sulphuric acid specific gravity 1.84	5

Strength of gas, 0.3931 ounce of cyanide per 100 cubic feet of space.
Effects of gas on rat No. 1 noticed in 1½ minutes.
Effects of gas on rat No. 2 noticed in 1½ minutes.
Effects of gas on rat No. 3 noticed in 4 minutes.
Effects of gas on rat No. 4 noticed in 4½ minutes.
Respiratory efforts of rat No. 1 ceased in 7 minutes.
Respiratory efforts of rat No. 2 ceased in 9 minutes.

Exact time of death of rats Nos. 3 and 4 could not be ascertained, as they ran into a corner of the room where they could not be observed. Upon subsequent examination of the room they were found dead.

Experiment No. 10.

Two rats were used, No. 1 in a wire cage, No. 2 loose on the floor.

	Ounces.
Amount of powdered commercial potassium cyanide	2
Amount of sulphuric acid specific gravity 1.84	2

Strength of gas, 0.1576 ounce of cyanide per 100 cubic feet of space.
Effects of gas on rat No. 1 noticed in 7½ minutes.
Effects of gas on rat No. 2 noticed in 1½ minutes.
Respiratory efforts of rat No. 1 ceased in 13 minutes.
Respiratory efforts of rat No. 2 ceased in 4½ minutes.

Experiment No. 11.

Four rats were placed at varying levels above the floor—No. 1 in a cage near the ceiling, directly over the generator; No. 2 in a cage on a trestle at the side of the room 2½ feet above the floor; Nos. 3 and 4 loose on the floor. On the trestle was placed a tin gallon measure containing 10 dog fleas (*Ctenocephalus canis*). In the bottom of this container was an inch of fine sand to afford protection for the fleas against the gas, should they be inclined to burrow therein. The floor was strewn with straw, sacks, and boards fastened together in the form of pipe casings. One of the loose rats was placed in a

box of this sort, both ends of which were tightly sealed with bundles of straw.

	Ounces.
Amount of powdered chemically pure potassium cyanide	6
Amount of sulphuric acid, specific gravity 1.84	6

Strength of gas, 0.4727 ounce of cyanide per 100 cubic feet of space.

Effects of gas on rat No. 1 noticed immediately.

Effects of gas on rat No. 2 noticed in six and one-half minutes.

Effects of gas on rats Nos. 3 and 4 could not be determined, as they were hidden under refuse on the floor.

Respiratory efforts of rat No. 1 ceased in one minute.

Respiratory efforts of rat No. 2 ceased in 14 minutes.

Both loose rats, as well as all fleas, were dead when removed after one hour's exposure.

Experiment No. 12.

Twelve young rats were released in the room, the floor of which had been strewn with straw, bags, boxes, etc. Twenty-four-hour Agar slant cultures of *B. diphtheria*, Staphylococcus, *B. typhosis* were also exposed to the gas for one hour.

	Ounces.
Amount of powdered chemically pure potassium cyanide	6
Amount of sulphuric acid, specific gravity 1.84	6

Strength of gas, 0.4727 ounce of cyanide per 100 cubic feet of space.

The rats were all dead after one hour's exposure. Some of them were found under the various articles of dunnage in different parts of the room. No effects on the cultures could be noticed.

Experiment No. 13.

A large quantity of miscellaneous dunnage consisting of bales of hay, straw, boxes, bags, pipe casing, boards, etc., was piled in the room. One rat was released in the room and cultures of *B. diphtheria*, *B. typhosis* and Staphylococcus were exposed to the gas.

	Ounces.
Amount of powdered chemically pure potassium cyanide	6
Amount of sulphuric acid specific gravity 1.84	6

Strength of gas, 0.4727 ounce of cyanide per 100 cubic feet of space.

After one hour's exposure the rat was found dead under bales of hay and straw. The cultures were not affected, with the exception of one of the Staphylococcus which was sterilized.

Experiment No. 14.

Five rats were liberated in the room in which had been placed a quantity of miscellaneous dunnage consisting of boxes and boards nailed in the form of pipe casings, together with a quantity of excelsior and bags filled with paper to simulate as closely as possible conditions ordinarily found in the hold of vessels. One rat was placed in a length of stovepipe, both ends of which were closed

with bundles of excelsior. Sufficient sulphur was burned to generate 4.34 per cent of sulphur dioxide gas in the room, which was closed for 12 hours. When opened all rats were found dead.

Experiment No. 15.

Nineteen rats were liberated in the room arranged as in the previous experiment, and one rat was placed in a length of iron stovepipe closed at each end with bundles of excelsior. In order that the rats might fully adapt themselves to conditions, some of them were placed in the room 36 hours before, others 24 hours before, and others immediately before the experiment was begun.

Sufficient sulphur was burned to generate over 3 per cent of sulphur dioxide gas and the room kept closed for six hours. When opened, 14 rats were found dead, while 6 were found alive and apparently unaffected. These latter had sought refuge under various articles of dunnage, and probably were protected by air pockets.

Experiment No. 16.

Fifteen rats were placed in the room and liberated. Six and one-half pounds of sulphur were burned. This was sufficient to generate 5.12 per cent of sulphur dioxide gas in the room.

After 5 hours and 45 minutes exposure, all rates were found dead. Some of these appeared still limp, as if they had just succumbed.

Experiment No. 17.

Five rats were liberated in the room and immediately took refuge under the dunnage. Sufficient sulphur was then burned to generate 4.34 per cent sulphur dioxide gas in the room, which was allowed to remain closed for four hours. When opened, all rats were dead. Two of them were found under the dunnage.

Experiment No. 18.

For this experiment six heavy galvanized cans 20 inches in diameter and 24 inches in depth, such as are ordinarily used for garbage receptacles, were selected.

A rat was placed in each can and the tops were covered with from one to six layers of cheesecloth. These cans were then exposed to 4 per cent sulphur dioxide gas for a period of six hours, after which the rats were removed and examined and the cans aired.

The experiment was immediately duplicated in exact detail, using cyanide gas instead of sulphur and replacing with a live one the dead rat killed by sulphur fumes in container No. 1. This gas was generated by using one-half ounce of potassium cyanide to each 100 cubic feet of space, as follows:

Potassium cyanide, 99 per cent	ounces	6½
Sulphuric acid, 93 per cent	fluid ounces	6½

The results obtained from this experiment are given in the following table:

Container.	Number of rats.	Cheesecloth protection.	Result with 4 per cent sulphur dioxide for six hours.	Result with ½ ounce KCN per 100 cubic feet for ½ hour.
No. 1	1	One-ply	Dead	Dead.
No. 2	1	Two-ply	Alive	Do.
No. 3	1	Three-ply	Unaffected	Do.
No. 4	1	Four-ply	do	Do.
No. 5	1	Five-ply	do	Do.
No. 6	1	Six-ply	do	Do.

Experiment No. 19.

This experiment was carried out in order to determine approximately the relative danger incurred in opening and entering spaces fumigated with hydrocyanic-acid gas.

For this purpose the forecastle and hold, and the superstructure (saloon and communicating staterooms) of a vessel were selected. One-half ounce of potassium cyanide per 100 cubic feet of space was used, and the compartments were allowed to remain closed for one hour.

The ventilation of the superstructure was rapidly and effectively secured by throwing open four doors. Upon the completion of the fumigation this was done and a rat immediately placed within. It was very shortly overcome.

Ten minutes later, however, the saloon and attached cabins were entered. No odor of cyanide gas was noticed and the men entering the place were unaffected.

Hold.—This space occupied the depth of two decks, was 37,500 cubic feet in capacity, and was ventilated through two hatches. Upon completion of the fumigation one of these was thrown open and rats were lowered at 5-minute intervals for 15 minutes. In this manner three rats were overcome by the gas, but in each instance were resuscitated. Both hatches were then removed. Fifteen minutes later a rat was lowered into the hold, but showed no ill effects.

Forecastle.—This compartment was of approximately 6,000 cubic feet capacity, and ventilated only through a small entrance door. Forty minutes after throwing open this door hydrocyanic-acid gas was present in sufficient strength to overcome rats, but did not affect two men who entered for a short time. The rooms were then entered and six portholes opened, and the chambers sufficiently cleared of gas in five minutes to permit rats being placed in them without showing any ill effects.

Summary.

(1) It early became evident that the use of 10 ounces of potassium cyanide per 1,000 cubic feet of space was unnecessary for efficient fumigation. As rapid and as effective results could be obtained by the use of much smaller quantities of the reagents. As a matter of fact, it was noticed that where lump potassium cyanide wrapped in cheesecloth or in other container was used, so that chemical action was retarded, the rats were dead before full chemical action had taken place. Several experiments therefore were performed with decreasing amounts of chemicals, the results of which indicated that the use of 5 ounces of potassium cyanide per 1,000 cubic feet of space was as effective as the use of 10 ounces per 1,000 cubic feet of space.

(2) It was clearly demonstrated that the quickest and best results were obtained by the use of powdered potassium cyanide, the chemical action being much facilitated and more rapidly completed. In several cases where such potassium cyanide was used the rodents were overcome immediately and seemingly were incapable of making any effort to escape.

(3) Two grades of potassium cyanide and sulphuric acid were used in these experiments, namely, chemically pure potassium cyanide and sulphuric acid (sp. g. 1.84) and commercial cyanide and sulphuric acid (66B). No material difference could be determined in the results obtained.

(4) Attempts to destroy bacteria with this fumigant were unsuccessful.

(5) It was noticed that where the rodents were allowed to run at liberty within the room during fumigation, and in the cases of the more active ones in cages, the effects of the gas were earlier apparent and more marked, and the rodents succumbed more quickly. Any physical efforts of the rodents seemed to hasten the effects of the gas, presumably by increased respiratory action.

(6) The cyanide gas apparently diffuses very rapidly, rising first to the top of a closed space, thence following along the walls to the floor, and finally reaching the center of the space. The progress of the gas during these experiments could very often be followed by observing its effects on fleas, mosquitoes, gnats, ants, etc., along the walls and floor of the room. From experiment No. 18 it is evident that cyanide gas is much more penetrating than sulphur dioxide, and is correspondingly to be preferred when fumigating ships loaded with cargo.

(7) While from the experiments, and more especially experiment No. 18 (in which unusual protection was afforded the test rats), it would seem that one-half hour is sufficient exposure when cyanide gas is used as the fumigant, the increasing of this period to one hour ought to suffice even when unusually large spaces are fumigated.

(8) The element of danger to human life is more or less speculative, and will vary according to the care exercised in performing the fumigation. In all the experiments no effect was noticed by those men who dropped the cyanide into the acid mixture. In the fumigation of a large warehouse the operators had to travel 100 feet from the container to the exit. This was accomplished without any noticeable effect.

In performing cyanide fumigation in ships' holds the dumping fixture operated by a rope, as indicated in the illustration on page 3549, will remove all possible danger to the operator. Ordinary speed in departing from the room will likewise safeguard the operator in fumigations on land where the cyanide is dropped by hand.

The danger in opening doors and windows or the hatches of vessels is likewise speculative, but in all these experiments and in several other instances no ill effect was ever noticed by those throwing open the doors and windows.

The room used for experiments could be entered without noticeable effect upon the operator five minutes after the door and window were thrown open. The size of the space fumigated and the draft resulting from natural air currents after the doors and windows have been opened have to be considered.

In experiment No. 19 it seemed evident that holds of ships would not retain the cyanide fumes so as to be dangerous to life 30 minutes after the hatchways were removed.

An accident on board a ship at New Orleans throws further light on this subject. This occurred during the fumigation of a superstructure on board. The room had a capacity of approximately 1,000 cubic feet. The cyanide was placed in the acid solution and the doorway sealed. A drunken sailor coming aboard threw open the door and entered. How long the man was exposed is uncertain. The exposure was not more than 15 minutes, and possibly only 5 minutes in duration. When discovered he was lying on the floor beside the cyanide container. It was likewise uncertain whether he had been overcome by the gas or had lain down in a drunken stupor. When removed from the room he was resuscitated.

The writers conclude that in any space where a circulation of natural air currents can be obtained there is no danger to men entering a place fumigated by cyanide gas 30 minutes after apertures have been opened. This interval of time is shorter than in sulphur fumigations, where the fumes are not sufficiently cleared from ships' holds for men to enter for varying periods of from one to three hours.

(9) The cost of cyanide fumigation, when the chemical is used in the proportion of 10 ounces of potassium cyanide per 1,000 cubic feet of space, is somewhat in excess of sulphur fumigation (4 per cent gas), the former costing from $17 to $25 per 100,000 cubic feet

of space, depending upon the market value of potassium cyanide, and the latter $13 per 100,000 cubic feet of space.

By reducing the amount of cyanide to 5 ounces per 1,000 cubic feet the cost per 100,000 cubic feet would vary from $8.50 to $12.50 in comparison with the cost of sulphur fumigation, i. e., $13 per 100,000 cubic feet of space.

From this it can be seen that effective cyanide fumigation can be performed at less expense for the chemicals alone than the sulphur fumigation prescribed in the quarantine regulations of the United States Treasury Department. The cost of equipment materially increases the disparity in expense.

(10) An itemized estimate of the comparative cost of sulphur and cyanide fumigation based on present market values is as follows:

With potassium cyanide at $0.25 per pound:

Potassium cyanide, 5 ounces, at $0.015625	$0.078125
Sulphuric acid, commercial, 8 ounces, at $0.00084375	.00675
Total	.084875

With potassium cyanide at $0.36 per pound:

Potassium cyanide, 5 ounces, at $0.0225	$0.1125
Sulphuric acid, commercial, 8 ounces, at $0.00084375	.00675
Total	.11925

The cost of fumigating like space with sulphur dioxide:

Sulphur, 4 pounds, at $0.022	$0.088
Methyl alcohol	.02
Total	.108

Sodium cyanide 126–133 per cent contains from one-fourth to one-third more available hydrocyanic acid gas than equal weight of potassium cyanide 97.99 per cent.[1] In fumigating, therefore, 3¾ ounces of sodium cyanide is the equivalent of 5 ounces of potassium cyanide. The price of sodium cyanide at present is $0.24 per pound. The cost of fumigating 1,000 cubic feet of space with this material, therefore, is:

Sodium cyanide, 3¾ ounces, at $0.015	$0.05625
Sulphuric acid, commercial, 5.62 ounces, at $0.00084375	.00474
Total	.06099

From this it will readily be seen that the cost of fumigating a given space with hydrocyanic acid gas compares very favorably with that of fumigating the same space with sulphur dioxide.

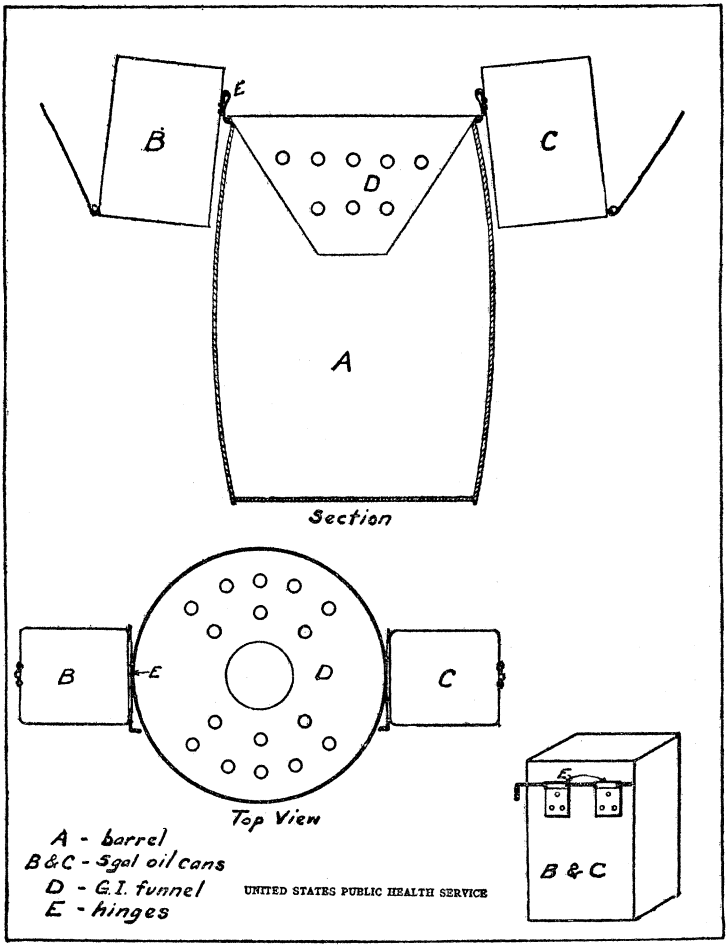
(11) It is somewhat difficult to estimate the cost of carbon monoxide (funnel gas) fumigation. The coke consumed is the least of the

[1] R. S. Woglum, Sodium cyanide for fumigation purposes, Bull. No. 90, U. S. Department of Agriculture, p. 84.

expense, for the maintenance of a tug or launch is essential to this method of fumigation.

To the price of coke must be added such items as the salaries and subsistence of the crew and the upkeep and depreciation of the fumigating vessel.

For the month of July, 1915, there were fumigated by carbon monoxide at New Orleans 58 vessels, in addition to those treated with sulphur or cyanide gas.



This period was selected at random and represented about the usual monthly average of ships fumigated at New Orleans. During this month the pay and subsistence of the crew of the fumigating tug *Neptune* was $1,518.40. The coke consumed amounted to $283.08, making a total of $1,801.48. The average cost per ship fumigated was therefore $31.06.

Averaging this amount for each 1,000 cubic feet of space fumigated, the cost would be slightly over 16 cents, in comparison with the unit price of 11 cents for sulphur fumigation, 8 to 12 cents for potassium cyanide, and 6 cents for sodium cyanide fumigation. Needless to observe, the increased cost of carbon monoxide would be very materially augmented were the depreciation of a $60,000 vessel and its machinery considered.

It should also be considered that the unit price of carbon monoxide fumigation would vary with the number of vessels fumigated, on account of the fixed overhead charge of the tug and crew maintenance.

The amount of fumigation work varies at different stations and fluctuates according to sanitary conditions, but it is believed that the monthly average of 58 ships would hardly be exceeded at any service station, and for the most part the number would be far less.

In order to facilitate the fumigation with hydrocyanic acid gas of holds of ships and other large spaces, where the escape of the operator after placing the cyanide in acid by hand is impossible, the following apparatus has been devised:

A. Ordinary wooden barrel, open at top, as the container for water and acid solution.

B–C. Five-gallon tins, with tops removed, and pin hinges placed on one side 2 inches below the top, made to fit similar hinges on sides of D. These tins hold cyanide.

D. Funnel of galvanized iron, 23 inches diameter at top, 12 inches perpendicular depth, 6 inches opening at bottom, series of 1-inch holes on sides opposite to hinges; hinges extending 2 inches above rim of funnel. It is intended that the acid and water mixture be placed in the barrel before it is lowered into the hold, the funnel to be then placed at the top of the barrel and the tins containing the cyanide attached to the funnel by means of the pin hinges. Ropes are attached to the bottom of the cans and passed over hatch combings. By simply pulling these ropes the contents of the cans are dumped into the barrel.

The advantages of this arrangement over the barrel and solution method are the great saving in time, labor, and apparatus required, and the more effective results obtained by the instantaneous liberation of the full amount of the gas.